Quality of yellow passionfruit (*Passiflora edulis* Sims f. *flavicarpa* Deg.) as affected by potassium nutrition

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Quality of yellow passionfruit (*Passiflora edulis* Sims f. *flavicarpa* Deg.) as affected by potassium nutrition.

Abstract — **Introduction**. The yellow passionfruit is consumed mainly as juice and is well accepted around the world. The nutritional state of the plant influences yield and fruit quality. We studied the particular effect of potassium nutrition on the quality of yellow passionfruit. **Materials and methods**. The experiments were conducted in a greenhouse at the Federal University of Viçosa, in Brazil, outlined in a randomized block design. The treatments were five concentrations of K [(1, 2, 4, 6 and 8) mmol·L^{-1}] in a modified nutritive solution of Hoagland and Arnon. The experimental unit consisted of one plant in a 20-L pot containing washed sand. The plants were irrigated by a circulating hydroponic system. The nutrients were re-added to the solution based on its electric conductivity and on the K content in each solution. **Results and discussion**. The K supply increased yield and average fruit weight up to the concentration of (6.43 and 6.24) mmol·L^{-1}, respectively, and linearly increased the number of seeds per fruit, thickness and relative water content of the pericarp and vitamin C content. The total titratable acid content increased according to a square equation, with the maximum point at 5.27 mmol K·L^{-1}. The pulp percentage, pH and total soluble solids content were not influenced by K doses. **Conclusions**. The increase in K supply promoted yield and fruit quality. At 90% of the maximum yield, the fruits had adequate quality traits.

Brazil / *Passiflora edulis* / plant nutrition / potassium / fruits / quality / yields

Qualité de la grenadille jaune (*Passiflora edulis* Sims f. *flavicarpa* Deg.) en fonction de la nutrition du plant en potassium.

Résumé — **Introduction**. La grenadille jaune est consommée principalement en jus et elle est partout bien acceptée. L'état nutritionnel des plants influence le rendement et la qualité des fruits. Nous avons étudié l'effet particulier de la nutrition en potassium sur la qualité de cette grenadille. **Matériel et méthodes**. Des expériences menées selon un dispositif en blocs randomisés ont été réalisées sous serre à l'université fédérale de Viçosa, au Brésil. Les traitements ont porté sur cinq concentrations de K [(1, 2, 4, 6 and 8) mmol·L^{-1}] testées dans une solution nutritive modifiée de Hoagland et Arnon. L'unité expérimentale a été constituée d'un plant dans un pot de 20 L contenant du sable lavé. Les plants ont été irrigués par un système d'alimentation hydroponique. Les éléments nutritifs ont été ajoutés aux solutions en fonction de leur conductivité électrique et de leur teneur en K. **Résultats et discussion**. L'ajout de potassium a augmenté le rendement et le poids moyen du fruit jusqu'à la concentration de (6,43 et 6,24) mmol·L^{-1}, respectivement, et accru linéairement le nombre de graines par fruit, l'épaisseur et la teneur en eau relative du péricarpe et le contenu en vitamine C. L'acidité titrable totale a augmenté selon une équation quadratique, avec un point maximum à 5,27 mmol K·L^{-1}. Le pourcentage de pulpe, le pH et la teneur en solides solubles totaux n'ont pas été influencés par des doses de K. **Conclusions**. L'augmentation de l'apport en potassium a favorisé le rendement et la qualité du fruit. À 90 % du rendement maximum, les fruits ont présenté des caractéristiques de qualité adéquates.

Brésil / *Passiflora edulis* / nutrition des plantes / potassium / fruit / qualité / rendement

1. Introduction

The yellow passionfruit (*Passiflora edulis* f. *flavicarpa*) is consumed mainly as juice. The fruit and the juice, as well as other industrialized products, are well accepted around the world. The juice is much appreciated due to its exotic flavor and nutritional value. It is a good source of provitamin A, niacin, riboflavin and ascorbic acid [1, 2]. The juice can be consumed pure or mixed with other fruit juices [3].

The nutritional status of the plant influences yield and fruit quality. Among the nutrients, N and K are the ones that most influence fruit quality. Fruit quality consists of several attributes, including physicochemical characteristics, nutritional value, purity, appearance, flavor, smell and consistency. Fruit quality is associated with the cultivar, the climate, the harvesting time and fertilization, among other factors [2, 4, 5].

Potassium is considered the nutrient of quality in horticulture. It plays a fundamental role in proteins, carbohydrates, sugars and organic acid synthesis, which are substances related to fruit quality. It participates in biochemical processes closely related to the photosynthesis and the inter-conversion of sugars [6].

The nutritional status influences external fruit traits, such as appearance, size, color and peel rugosity, and internal characters such as juice content, soluble solids content, acidity and physiological disorders. These effects are variable among the species [7, 8].

The objective of our paper was to assess the role of potassium on the yield and quality of the yellow passionfruit.

2. Materials and methods

The experiment was conducted in a greenhouse covered with polyethylene film and lateral screen walls in the Plant Crop Department of the Federal University of Viçosa, in Viçosa, Minas Gerais, Brazil, from January to October 1999.

A randomized block design with five treatments and four replications was used. The treatments consisted of five concentrations of K [(1, 2, 4, 6 and 8) $mmol \cdot L^{-1}$] in a modified number 1 Hoagland and Arnon [9] nutritive solution. The experimental units were composed of a 20-L pot containing one plant. The pots were spaced at (0.5 × 1.0) m. Hybrids were used to reduce the genetic variability among the plants. A different hybrid was used in each block to avoid hindering fructification due to self-incompatibility [10].

The experiment was conducted in a hydroponic system, consisting of five 80-L reservoirs, destined to store the treatment solutions. One plot in each block was irrigated by gravity by the respective nutritive solutions, at 10 L per h. Sand washed with NaOH and HCl was used as substrate. The drained volume from each plant pot was collected and pumped back into the original treatment reservoir. The consumed water was replaced daily.

The salts were re-added to the solutions based on the electric conductivity and on the K content in each solution. From January to June, a maximum depletion of 60% was adopted. After June, the re-additions were based on depletion of 20%. From January to July, nutritive solutions of one ionic strength were used, and after that the ionic strength of the solution was raised to 1.2. The solutions were changed every 15 days. The pH of the nutritive solution was adjusted daily to 6.0, using HCl or NaOH.

The vines were arranged vertically with metal wire. Each plant was guided as a single stem onto the wire, and then into two horizontal branches in opposite directions, along the wire. Each secondary horizontal branch was pruned after four shoots. Five flowers of each of the eight pending shoots were hand-pollinated with a mixture of pollen from the four hybrids.

The evaluated variables were:

– Yield (kg per plant).

– Fruit weight (g) obtained from ten sampled fruits per plant.

– Number of seeds per fruit, obtained from ten sampled fruits per plant.

– Pericarp thickness measured at two points of the pericarp after a transversal cut.

– Pulp percentage obtained from the ratio [weight of the pulp without the seeds / weight of the fruit], of ten sampled fruits per plant.

– Relative water content of the pericarp, determined according to Catsky [11], using the following equation: $\phi = [(FM - DM) / (TM - DM)] \times 100$, in which FM is the mass of fresh material (g), DM is the mass of dry material (g), and TM is the mass of turgid material (g). Four 7-mm-diameter pericarp disks were used per fruit. The disks were removed from the equatorial region of the fruit, immediately weighed to obtain FM, then put on a water-saturated sponge for 14 h to obtain TM. Later, they were dried in an oven with air circulating at 70 °C until constant mass, and then weighed to obtain DM.

– Juice pH, determined on a potentiometer.

– Vitamin C content, obtained by Tillmans' method (2,6 dychlorophenol indophenols at 0.02 $g \cdot L^{-1}$), recommended by AOAC [12].

– Total titratable acidity, expressed in g citric acid·100 mL^{-1} juice. It was determined according to the methodology recommended by AOAC [12]. Three repetitions were done per plot.

– Total soluble solids content, determined by a portable refractometer, with the reading zone from (0 to 32) °Brix, after extraction and homogenizing of the juice of ten fruit per plot.

Data were submitted to variance and regression analyses, at the 5% significance level for the *F* test. The regression models were adjusted, associating the variables with the applied K concentrations. The biological significance of the model, high determination coefficient and the significance of regression coefficients ($P \leq 0.10$) were adopted as criteria for the choice of regression models.

The concentration of K that proportioned the maximum yield per plot, corresponding to the maximum physical efficiency (MPE), was calculated by the first derived equation. Due to the occurrence of little yield variation around the maximum point, the K concentration corresponding to the maximum economic efficiency (MEE) was calculated, considered to be 90% of the MPE, as considered for critical deficiency content [13].

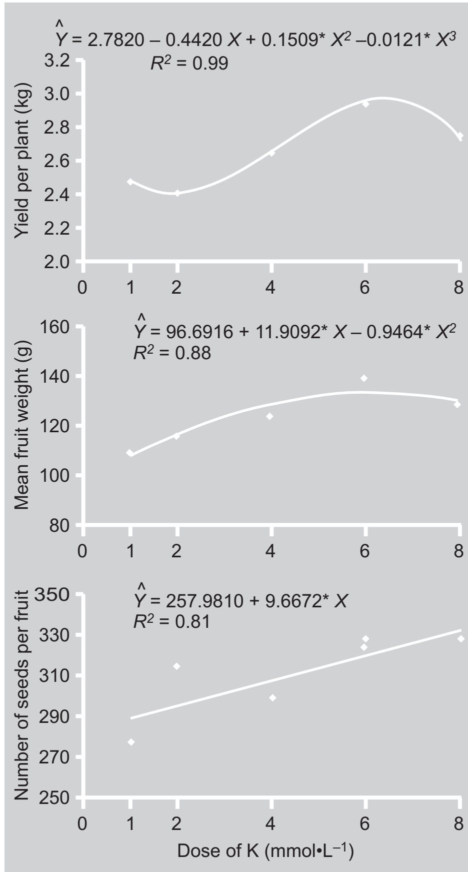

Figure 1.
Production of fruit per plant, mean fruit weight and average number of seeds per fruit of the yellow passionfruit plant grown in a nutritive solution, in relation to doses of K.

The values of the other evaluated variables corresponding to the MEE K concentration were determined based on the equation of each variable.

The software System of Statistical and Genetic Analyses (SAEG, version 8.0) was used.

3. Results and discussion

Potassium exerted a significant effect on yield. The maximum physical efficiency yield (MPE) was estimated as 2.96 kg per plant, obtained with the concentration of 6,43 mmol $K \cdot L^{-1}$ in the nutritive solution (*figure 1*). Eight months after planting, the K foliar content was 0.0221 $g \cdot kg^{-1}$ [14], similar to the contents considered adequate by Primavesi and Malavolta [15] and Menzel *et al.* [16]. The maximum economic efficiency yield (MEE) was 2.68 kg, estimated at the concentration of 4.08 mmol $K \cdot L^{-1}$.

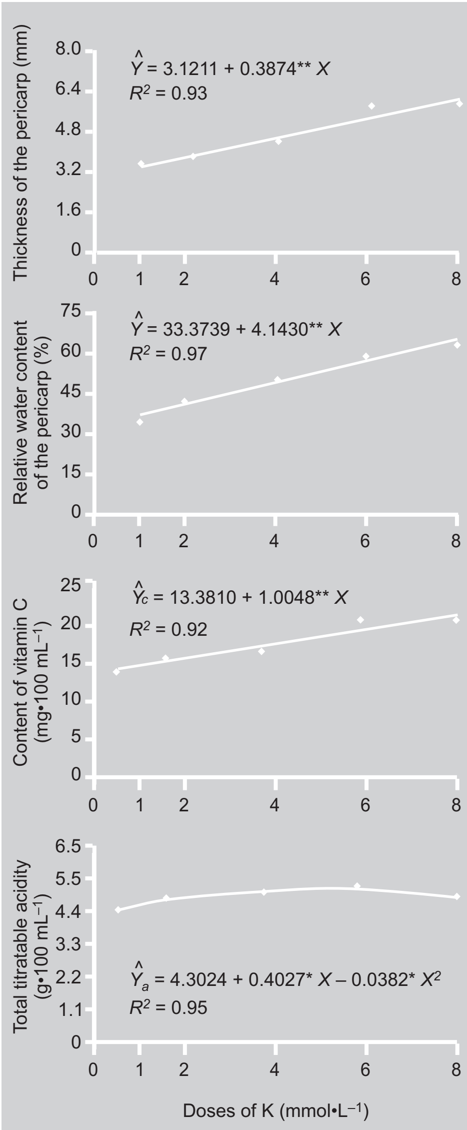

Figure 2.
Thickness of the pericarp, relative water content of the pericarp, content of vitamin C and total titratable acidity of the yellow passionfruit plant grown in a nutritive solution, in relation to doses of K.

Fruit weight increased according to a quadratic equation up to the K concentration of 6.24 mmol $K{\cdot}L^{-1}$. The MEE K concentration resulted in fruit weight of 129.12 g (*figure 1*). Potassium participates in the metabolic activities related to carbohydrate synthesis and transport of water, which favor the fruit expansion [13, 17, 18].

A linear increase in seed number per fruit was noted with the increase in the K concentration (*figure 1*). At the MEE K concentration, there were 297 seeds per fruit. Quaggio and Piza Jr. [19] verified that K deficiency leads to fewer and atrophied seeds in some passionfruits. Waters *et al.* [20], studying the influence of sucrose and abscisic acid in the determination of the number of grains in wheat, verified that seed number per plant can also be increased by high sucrose content before the initial flower budding. Since K is directly involved in the transport of this sugar, it possibly influences that variable.

The influence of seed number on fruit quality is variable among the species and the mechanisms involved in quality expression are not well understood. However, hormones have important effects on the processes. Seeds contain tissues with high hormone synthesis activity, which acts on the sink potential of the fruit [21]. These authors verified that in apple trees there are positive linear correlations between seed number and fruit length, width, weight and juice content, probably because new seeds are expressive sources of auxins, which influence cell growth. In passionfruit, greater seed quantity results in higher juice content, because the juice is contained in the aril, which surrounds the seed.

Pericarp thickness was increased linearly with the K concentrations (*figure 2*). The pericarp thickness was 4.7 mm at the MEE K concentration. Potassium, being the most abundant cation in the cytoplasm, gives the greatest contribution to the osmotic potential of the cells and tissues, and is strongly linked to the hydric relations of the plant.

The relative water content in the pericarp increased linearly with the K concentrations (*figure 2*). At the MEE K concentration it was 50.3%. The relative water content is an indicator of the hydric oscillation in the plant. Because it influences opening and closing of the pores and osmotic regulation, potassium has an important role in controlling the water content in plant tissues [16]. In treatments with higher concentrations of K, there was probably higher accumulation of water in the fruits, part of it stored in the peel, which presents a spongy characteristic. High water content in the peel is important for the post-harvest of passionfruit, which loses its quality due to wilting caused by dehydration.

The vitamin C content increased linearly with the K concentrations (*figure 2*). The vitamin C content corresponding to MEE was 17.48 mg·100 mL^{-1} of ascorbic acid in the juice. The fruits synthesize the ascorbic acid from hexose sugars, originally D-glucose or D-galactose [22]. Potassium is directly involved in the metabolism of carbohydrates by means of activation of certain enzymes which require large amounts of K [18, 23]. Potassium deficiency can inhibit biosynthesis of sugars, organic acids and vitamin C [24, 25].

The total titratable acid, expressed in citric acid (g·100 mL^{-1}), showed a quadratic function in relation to K concentrations (*figure 2*). At the concentration of K corresponding to MEE, it was 5.31 g·100 mL^{-1} juice. According to Chan Jr. *et al.* [1], citric acid is the predominant organic acid in yellow passionfruit (83%), followed by malic (16%), lactic, malonic and succinic acids.

Organic acids in plants are primary products of photosynthesis and act as a forerunner of the synthesis of fat acids, carbohydrates and proteins. The acidity raised by organic acids is an important trait for good flavor of many fruits. In many species, a narrow relationship between total acidity and content of K was observed [26].

The cycle of citric acid has an important role in the metabolism of carbohydrates. It is an energy source for plant cells, because it recuperates the remnant energy linked to sugars, which has not yet been released by glycolysis [27]. Potassium activates enzymes involved in respiration and photosynthesis [6].

There were no significant effects of the K concentrations on pulp percentage, juice pH or total soluble solids content. The average pulp percentage was 56.28%, above those observed by Meletti [28] and Enamorado *et al.* [29]. The mean pH value was 2.76, characteristic of acid fruits such as passionfruit. The average content of total soluble solids was 16.83 °Brix. The soluble solids content of yellow passionfruit is reported to vary from (12 to 17) °Brix, due to genetic variability and different localities and harvesting conditions [5, 30]. Carvalho [5] observed higher total soluble solids content in yellow passionfruit due to higher K concentrations in an experiment with irrigation depth and concentrations of K. He found values from (13.3 to 14.4) °Brix.

4. Conclusions

The increase in K supply promoted the increase in yield and quality of yellow passionfruit.

At the concentration of K corresponding to MEE, the fruits presented adequate quality traits.

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Calidad de la granadilla amarilla (*Passiflora edulis* Sims f. *flavicarpa* Deg.) en función de la nutrición de potasio de la planta.

Resumen — **Introducción**. La granadilla amarilla se consume principalmente en forma de zumo y se acepta favorablemente en todos los lugares. El estado nutricional de las plantas influencia el rendimiento y la calidad de los frutos. Estudiamos el efecto particular de la nutrición de potasio en la calidad de esta granadilla. **Material y métodos**. En la universidad federal de Visçosa, en Brasil, se realizaron experimentos en invernadero de acuerdo con un dispositivo en bloques aleatorios. Los tratamientos se refirieron en cinco concentraciones de K [(1, 2, 4, 6 y 8) $mmol·L^{-1}$] testados en una solución nutritiva modificada de Hoagland y Arnon. La unidad experimental se constituyó de una planta en un macetero de 20 L con contenido de arena lavada. Se regaron las plantas por un sistema de alimentación hidropónico. Se añadieron a las soluciones los elementos nutritivos en función de su conductividad eléctrica respectiva y de su contenido en K. **Resultados y discusión**. El añadido de potasio aumentó, por un lado, el rendimiento y el peso medio del fruto hasta la concentración de (6,43 et 6,24) $mmol·L^{-1}$, respectivamente ; y, por otro lado, aumentó linealmente el número de las semillas por fruto, el grosor y el contenido de agua relativo al pericarpio, así como el contenido de vitamina C. La acidez valorable total aumentó según una ecuación cuadrática, con un punto máximo de 5,27 $mmol\ K·L^{-1}$. El porcentaje de la pulpa, el pH y el contenido en sólidos solubles totales no se influenciaron por las dosis de K. **Conclusiones**. El aumento del aporte de potasio favoreció el rendimiento y la calidad del fruto. Con un 90% del rendimiento máximo, los frutos presentaron unas características de calidad adecuadas.

Brasil / *Passiflora edulis* / nutrición de las plantas / potasio / fruto / calidad / rendimiento